Construction of an Oyster Shell Habitat Plot in Elliott Bay: Evaluation of Crab Settlement and Habitat Utilization in 1998

Elliott Bay/Duwamish Restoration Program

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Abstract

A small-scale subtidal oyster shell reef was constructed in Elliott Bay at Seacrest Park during spring, 1998 as part of on-going Elliott Bay/Duwamish Restoration Program efforts to improve local estuarine habitats. The shell plot and a nearby "control" eelgrass area were monitored on two sampling dates in summer 1998 for settlement of juvenile Dungeness crab, *Cancer magister*. Low densities of juvenile Dungeness crab were found in the intertidal eelgrass, but no Dungeness crab were found in the subtidal shell. However, other crab species and fish and invertebrate fauna were found in the shell plot. Dungeness crab settlement in the shell plot might have been prevented by low larval abundance, the subtidal location of the shell plot, and/or its location in inner Elliott Bay near the discharge of the Duwamish River. Recommendations are presented for future shell plot experimentation.

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Introduction

Adult Dungeness crab, *Cancer magister*, are found throughout most of Puget Sound and Hood Canal, although their densities in Puget Sound are minimal from Seattle southward. Juvenile Dungeness crab require intertidal and shallow subtidal nursery areas, where their 6-12 months post-larval residency affords them protection from predation by fishes and larger crabs. Key shallow-water habitat types for juvenile Dungeness crab in Puget Sound include eelgrass (*Zostera marina*), shell, and gravel overlain by algae. Those areas devoid of these habitat types do not support juvenile Dungeness crab (McMillan et al. 1995).

Lessons from San Francisco Bay strongly suggest that Dungeness crab population strength is directly proportional to the amount and quality of juvenile habitat present in a given estuary. Prior to 1960, commercial Dungeness crab landings from the San Francisco Bay area fluctuated between 4 and 9 million pounds annually. Landings decreased to less than 0.5 million pounds in the 1960's and have remained below 0.5 million pounds since (Farley 1983). Suspected causes of this decline were physical loss of nearshore nursery habitats and degradation of remaining habitats by pollution.

This same destruction of nearshore nursery habitats has occurred in the urban embayments of Puget Sound. Elliott Bay has suffered a loss of about 98% of its estuarine wetlands (NOAA 1993) and Commencement Bay has suffered a similar fate. Now, few Dungeness crab are to be found in these two embayments (Dinnel et al. 1986a) where adult habitat is plentiful. It is quite possible that loss of most nursery habitats in these two major embayments has greatly reduced adult populations, including female spawners that may have once been the source of larvae that settled in, and restocked the south Puget Sound basin.

If lack of nursery habitat is indeed the factor limiting adult crab populations in south Puget Sound, then it seems reasonable to conclude that creation/restoration of nursery habitat would aid Dungeness crab populations. Indeed, this concept has been tested and validated in Grays Harbor, Washington during the last decade.

In Grays Harbor, channel dredging by the U. S. Army Corps of Engineers (COE) entrains and kills a substantial number of Dungeness crab. During a recent project to widen and deepen the navigation channel in Grays Harbor, mitigation was required for the projected mortality of Dungeness crab (COE 1988, 1989). One facet of the mitigation was the construction of oyster shell reefs on barren sand/mud flats to provide supplemental nursery habitat for young-of-the-year (YOY) crab. The amount of shell habitat required was derived from a model that integrated settlement densities in shell, crab growth, and natural mortality rates (Wainwright et al. 1992). While success of the Grays Harbor crab mitigation effort has been mixed due to shell loss (sinkage and/or sedimentation) and by unanticipated competition from the shore crab, *Hemigrapsus*, the shell mitigation program has continued through 1998 (Armstrong et al. 1992, 1995; Dinnel Marine Research 1996; Dumbauld et al. 1993; Visser 1997).

The concept of creating juvenile Dungeness crab habitat using oyster shell was initiated in Elliott Bay in early 1998 with the deployment of about 10 yd^3 of oyster shell just offshore of Seacrest Park on the eastern side of Duwamish Head. The goal of the work reported below was to sample the oyster shell plot for settlement, survival and growth of juvenile Dungeness crab and related crab species. The project was sponsored by the Elliott Bay/Duwamish Restoration Program, a panel of local, state, and federal agencies and Native American Tribes responsible for implementing a natural resource damages settlement reached with the City of Seattle and METRO. King County Department of Natural Resources was the designated project manager.

Methods

About 10 yd^3 of oyster shell was deployed by barge and crane in spring 1998. The shell covered an area of roughly 10 by 20 m at a shell layer depth of about 5-10 cm. The shell plot was located at water depths of -2 to -5 m MLLW just south of the Seacrest Park boat launch (Figure 1). The bottom type in the shell plot area was mixed sand/gravel/cobble with moderate algae cover. A floating fish pen was located to the seaward side of the shell plot (Figure 1).

The oyster shell plot was sampled twice (23 July and 18 August) for crabs and associated fauna during the summer of 1998. The shell plot was sampled on both occasions by divers using a hand-held venturi suction dredge (Figure 2). Ten samples were collected on each date by working the nozzle of the suction dredge between the oyster shells within a 1/4 m^2 metal frame. Crabs and associated fauna were sucked into a mesh bag, which could be exchanged for a new bag at the end of each sample effort. On shore, each sample was sorted, crabs identified and measured (most species), other organisms identified to major taxonomic group, and the animals returned live to the bay.

In addition to the shell plot samples, ten samples were collected on each date from eelgrass beds on the NW side of Duwamish Head, approximately 0.5 miles northwest of Seacrest Park (Figure 1). These samples served as "control" samples that provided data about natural Dungeness crab settlement densities and sizes in the Elliott Bay area. The control samples were collected intertidally at low tide by digging 1/4 m^2 quadrat samples to a depth of about 2 cm and washing the samples in a mesh bag with mesh size of about 3 mm.

Results

Basic catch and size statistics for crabs collected in the 23 July and 18 August samples are summarized in Tables 1 and 2, respectively.

23 July Samples

Of the crab species collected during the 23 July sampling, Dungeness crab were highest in density in the eelgrass beds (control area), compared to the other crab species present (Table 1). However, an average density of only 2.8 crab/m^2 in prime settlement habitat for this species indicates that significant settlement had not yet taken place in Elliott Bay this year. Densities of juvenile Dungeness crab in similar habitat in the north Puget Sound region (Padilla Bay/Guemes Island) were in the range of 40-100/m^2 during the same period of time (unpublished data collected by Paul Dinnel).

Sizes of Dungeness crab caught at the eelgrass control site on 23 July are compared in Figure 3 to Dungeness crab sampled at March Point near Anacortes, WA on 24 July. It appears that YOY Dungeness crab present at both locations likely originated from the same "pulse" of larval recruits.

Table 1. Average number of crabs caught in the 23 July samples together with their estimated densities and average sizes by carapace width (CW).

Species	Average # of Crab/Sample	Estimated Density (Crab/m^2)	Average Size (mm CW)
Eelgrass (control)			
Cancer magister	0.7	2.8	10.4
Cancer gracilis	0.2	0.8	9.1
Cancer oregonensis	0.2	0.8	5.0
Oyster Shell			
Cancer magister	0.0	0.0	------
Cancer productus	0.5	2.0	27.0
Cancer oregonensis	4.1	16.4	6.0
Hemigrapsus sp.	1.6	6.4	13.2
Kelp crab, *Pugettia* sp.	a few small ones noted but not counted or measured		
Hermit crabs	Ditto		

No Dungeness crab were found in the oyster shell samples on 23 July. The dominant crab species in the oyster shell were Oregon rock crab, *Cancer oregonensis* (Table 1). All of the *C. oregonensis* collected from the shell were small YOY crab that had probably settled in the shell since its deployment. Sizes of the shore crab, *Hemigrapsus*, suggest that they immigrated into the shell from surrounding areas or were present in the gravel/cobble bottom prior to shell placement. All but one of the red rock crab, *Cancer productus*, were 1+ years old (25-40 mm CW); the exception was one individual at 5.0 mm CW that must have settled in the shell as a late stage larva.

18 August Samples

Juvenile Dungeness crab were again the dominant crab species collected in the eelgrass samples at Duwamish Head on 18 August (Table 2).

Table 2. Average number of crabs caught in the 18 August samples together with their estimated densities and average sizes by carapace width (CW).

Species	Average # of Crab/Sample	Estimated Density (Crab/m^2)	Average Size (mm CW)
Eelgrass (control)			
Cancer magister	1.9	7.6	7.6
Cancer gracilis	0.1	0.4	22.2
Cancer oregonensis	0.3	1.2	6.1
Oyster Shell			
Cancer magister	0.0	0.0	------
Cancer productus	0.5	2.0	14.4
Cancer oregonensis	4.0	16.0	7.5
Hemigrapsus sp.	3.2	12.8	10.3
Kelp crabs, *Pugettia* sp.	0.9	3.6	NM
Porcelain crabs, *Petrolisthes* sp.	1.8	7.2	NM
Hermit crabs	a few small ones noted but not counted or measured		

The density of YOY Dungeness crab in the eelgrass "control" area increased from the July estimate of 2.8/m^2 to 7.6 crab/m^2 on 18 August. Size-frequency distributions for these crab and Dungeness crab collected from March Point on 8 August are shown in Figure 4. Size-frequency distributions shown in this figure suggest two "pulses" of settlement: The first pulse of settlement occurred in June and July, while the second pulse occurred in August. The first pulse of settlement was probably composed of larvae that had been flushed into Puget Sound from the Pacific Ocean during the winter months ("ocean cohort"). The second settlement pulse was typical of Puget Sound-spawned larvae ("Puget Sound cohort" -- see Dinnel 1993). YOY Dungeness crab settling in August in both locations were distinctly from the "Puget Sound cohort" by virtue of their later settlement time and the smaller sizes of the 1st instars (1st post-larval benthic stage). First instar YOY Dungeness crab collected in July were always ≥5.0 mm CW, whereas 1st instars collected in August were usually in the range of 4.5-5.0 mm CW.

Once again, no Dungeness crab were collected from the oyster shell plot in August. The dominant species were once again YOY *C. oregonensis* followed by *Hemigrapsus* (Table 2).

Discussion

The initial idea for creation of juvenile Dungeness crab habitat in Elliott Bay by establishing oyster shell plots was proposed by Dinnel (1993) in a concept paper to the Elliott Bay/Duwamish Restoration Program. In that concept paper, Dinnel proposed the following:

> "Establish oyster shell reefs at one or more marine restoration sites in Elliott Bay. Shell can be applied in "landscape" fashion (integrated with other habitat types) in intertidal and subtidal areas. Intertidal shell is especially valuable for very small, newly recruited post-larvae, while subtidal shell is important as refugia for 1-year old crabs (subtidal shell can also provide new recruit habitat, but its effectiveness for this has yet to be tested)."

The primary factor limiting Dungeness crab populations in Elliott Bay, and probably most of southern Puget Sound, seems to be an adequate amount of intertidal habitat suitable for juvenile nursery areas. The concept of shell deployment was primarily aimed at increasing this type of habitat in intertidal areas. However, no satisfactory intertidal location for the deployment of a shell plot was available in the project area. Thus, the oyster shell plot was constructed subtidally.

Results of other Dungeness crab studies (e.g., Dinnel 1986b, 1987; Fernandez et al. 1993; Fernandez 1994; McMillan et al. 1995) strongly suggest that upon settlement, megalopae (the last larval stage) seek out intertidal habitats that offer refuge from predation. While it is probable that some megalopae do settle in subtidal zones, their numbers appear to diminish rapidly as they are preyed upon by fishes and larger crabs. Thus, the placement of the oyster shell plot in a subtidal configuration left open the question of its ability to attract megalopae and successfully nurture the resulting juvenile crab.

Another limiting factor in the success of created/restored habitat to serve as juvenile Dungeness crab nursery habitat is the larval supply. If few larvae reach the shell plot, then few crab will be produced. Densities of juvenile crab observed in eelgrass in the Duwamish Head "control" area in summer 1998 were quite low compared to north Puget Sound (2.8-7.6/m^2 at Duwamish Head vs. 40-100/m^2 at March Point). Although no juvenile Dungeness crab were found in the shell plot, the potential for attracting Dungeness crab larvae was very limited due to the overall low abundance of larvae in Elliott Bay in 1998.

Another possible factor limiting the success of the shell plot was its location. The supply of larvae may have been less on the inner side of Duwamish Head as compared with the more exposed, higher saline conditions on the NW side of Duwamish Head. Typically, a plume of surface freshwater extends northward from the mouth of the Duwamish River into Elliott Bay. This freshwater plume may have minimized the number of larvae present in inner Elliott Bay due to current patterns and/or reduced salinity, which the larvae may have sensed and avoided. Possibly, settlement of Dungeness crab larvae might have been enhanced if the shell plot had been located near the "control" eelgrass beds on the NW side of Duwamish Head. Ideally, intertidal sites might yet be found (or created) for future shell plot deployments.

Another interesting future possibility is the "seeding" of created shell plots with YOY Dungeness crab. The senior author of this report recently proposed such a concept to the National Sea Grant Program (Dinnel and Sulkin 1998) for reestablishing Dungeness crab into south Puget Sound (south of the Tacoma Narrows). In recent years, salmon net pen operations at Cypress Island in the San Juan Archipelago have been plagued by thick swarms of Dungeness crab megalopae in the net pens. These larvae become entrained in the salmon gills, causing lesions and stress, which apparently contribute to increased mortality and generally poor health. The Sea Grant proposal suggested the possibility of capturing the nuisance megalopae (by the millions) and transporting them to appropriate intertidal habitats in south Puget Sound. This same concept could be used to seed oyster shell plots (or natural eelgrass beds) in Elliott Bay or other areas. In this case, megalopae would be allowed to metamorphose to the 1st instar benthic stage in laboratory tanks before seeding into shell plots.

Recruitment of crabs into the oyster shell plot is clearly taking place. All of the *Cancer oregonensis* and at least one of the *C. productus* had to have settled in the shell as larvae. If these two species can successfully recruit to the shell, so can Dungeness crab under the right circumstances. Two changes might encourage future settlement of Dungeness crab: 1) shallower placement of the shell, especially in intertidal areas, and 2) relocation of future shell plots to the NW side of Duwamish Head. However, these two suggested changes must be balanced with two possible opposing forces: 1) social-political decisions regarding placement of shell on beaches commonly used by the public, and 2) possible disruption of the shell plots by wave action or burial by sinkage or sedimentation. Several additional shell plots deployed in 1999 would help to answer some of these unknowns, *if* significant Dungeness crab larvae are present in Elliott Bay during the summer of 1999.

The primary objective of this study was to assess the utility of oyster shell to serve as juvenile Dungeness crab habitat. Clearly, the constructed shell plot provided complex habitat that serves the needs of a variety of other fauna. Other fauna found in the shell included small shrimp, polychaetes, amphipods and gunnels. Many of these animals will serve as food chain organisms for larger fishes and invertebrates. Future parallel investigations into the value of shell habitat for these organisms should also be conducted.

Conclusions and Recommendations

1. Only light settlement of Dungeness crab larvae occurred in Elliott Bay during 1998. Relatively few early instars were found in the "control" eelgrass area. No Dungeness crab were found in the subtidal oyster shell plot on either sampling trip.

2. The oyster shell plot retained its integrity during the summer of 1998 and served as habitat for various other crab species, shrimp, amhipods, polychaetes and gunnels. Two crab species related to Dungeness crab (*Cancer oregonensis* and *C. productus*) probably recruited into the shell from larvae.

3. Recommendations for future shell plot experimentation include: 1) relocation of shell to intertidal or shallower subtidal areas, 2) relocation of shell to the NW side of Duwamish Head, and 3) "seeding" of shell plots with 1st instar crab collected form fish pens in north Puget Sound. Seeding of this type could also help supplement juvenile crab populations in the natural eelgrass beds at Duwamish Head.

4. Evaluate the value of constructed shell plots for all fauna, especially the more valuable food chain organisms.

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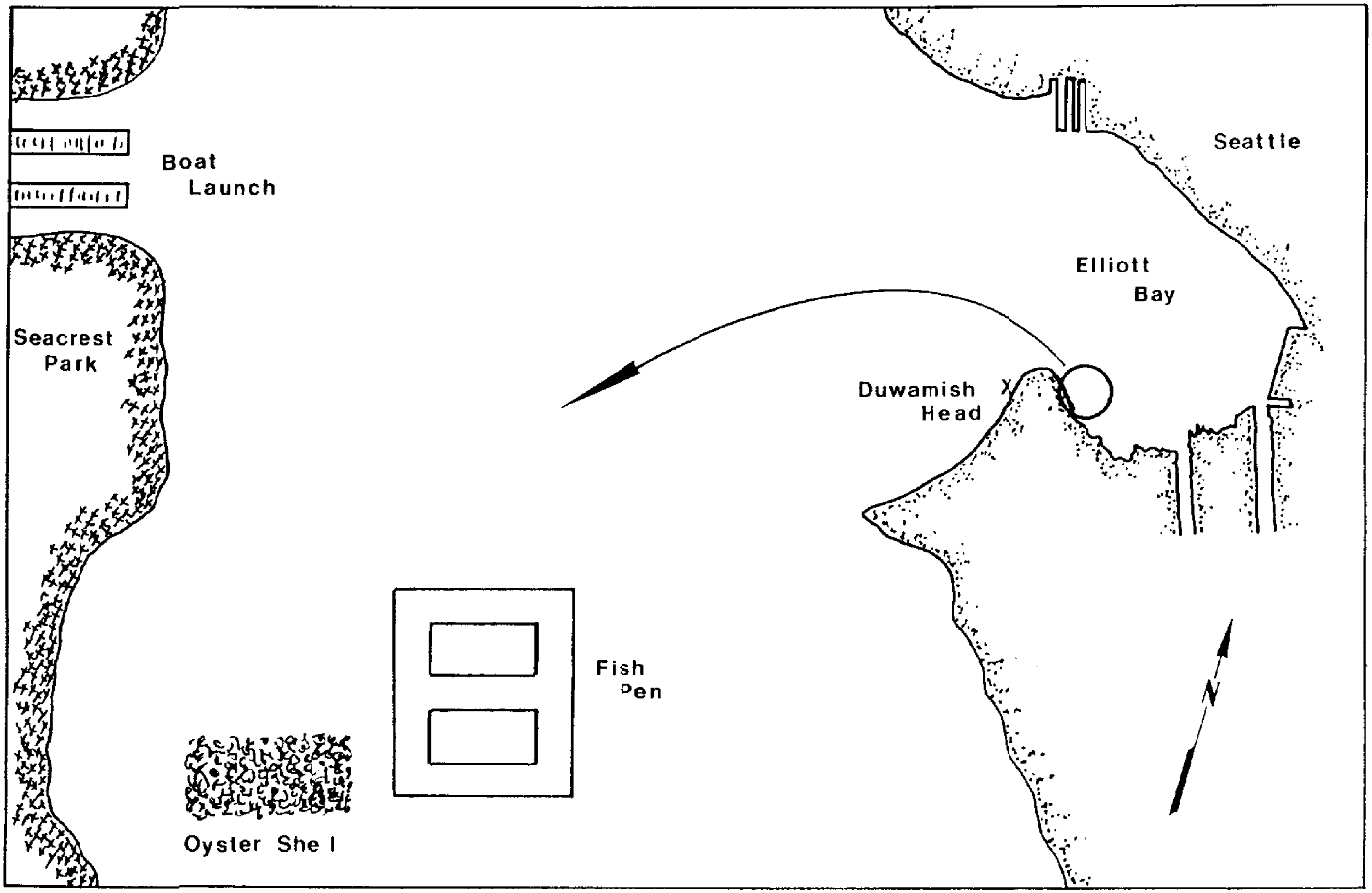

Figure 1. Location of the oyster shell plot in Elliott Bay (right) and a site view of the shell plot located offshore of Seacrest Park. An "X" marks the spot of the eelgrass "control" site on the northwest side of Duwamish Head.

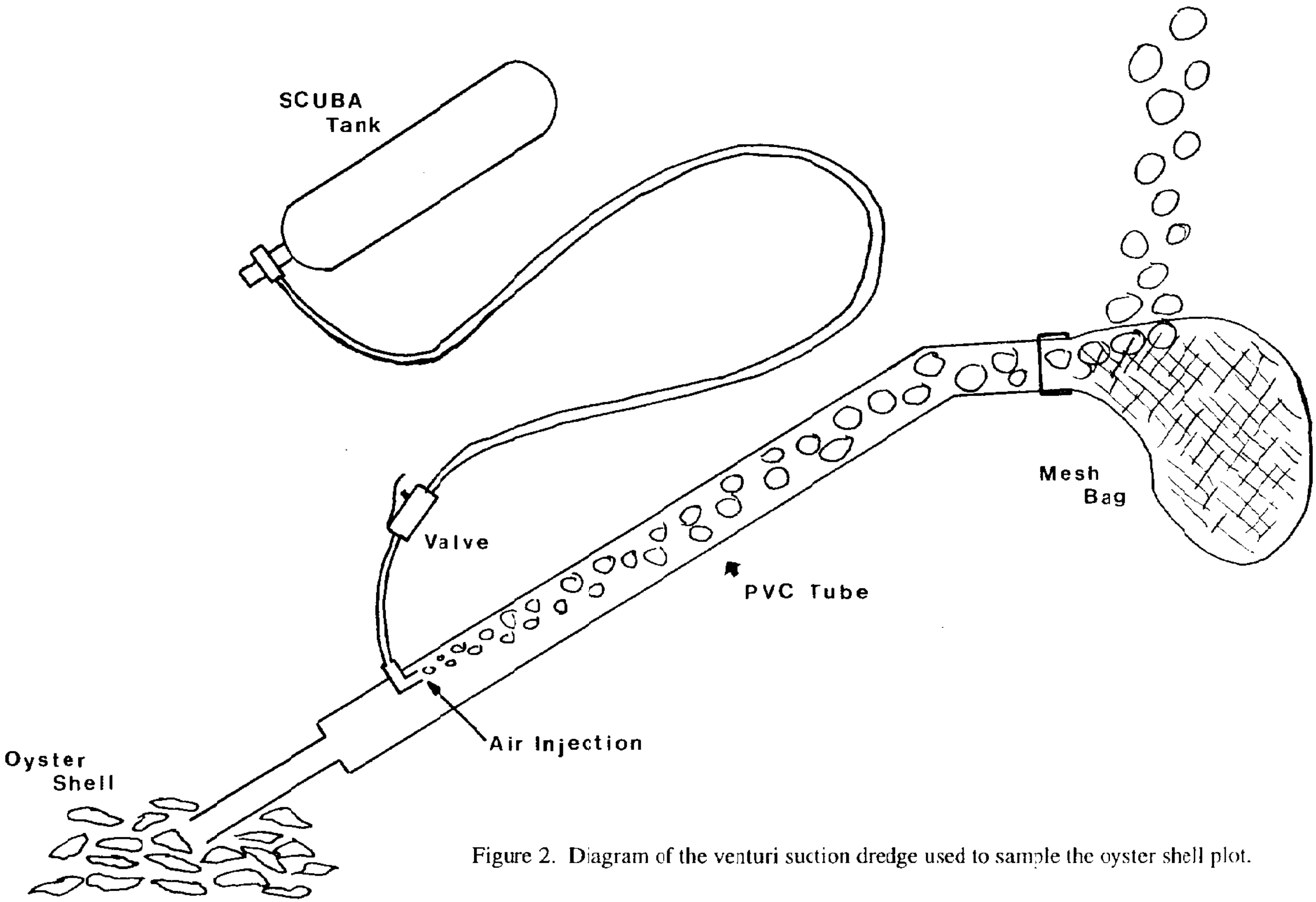

Figure 2. Diagram of the venturi suction dredge used to sample the oyster shell plot.

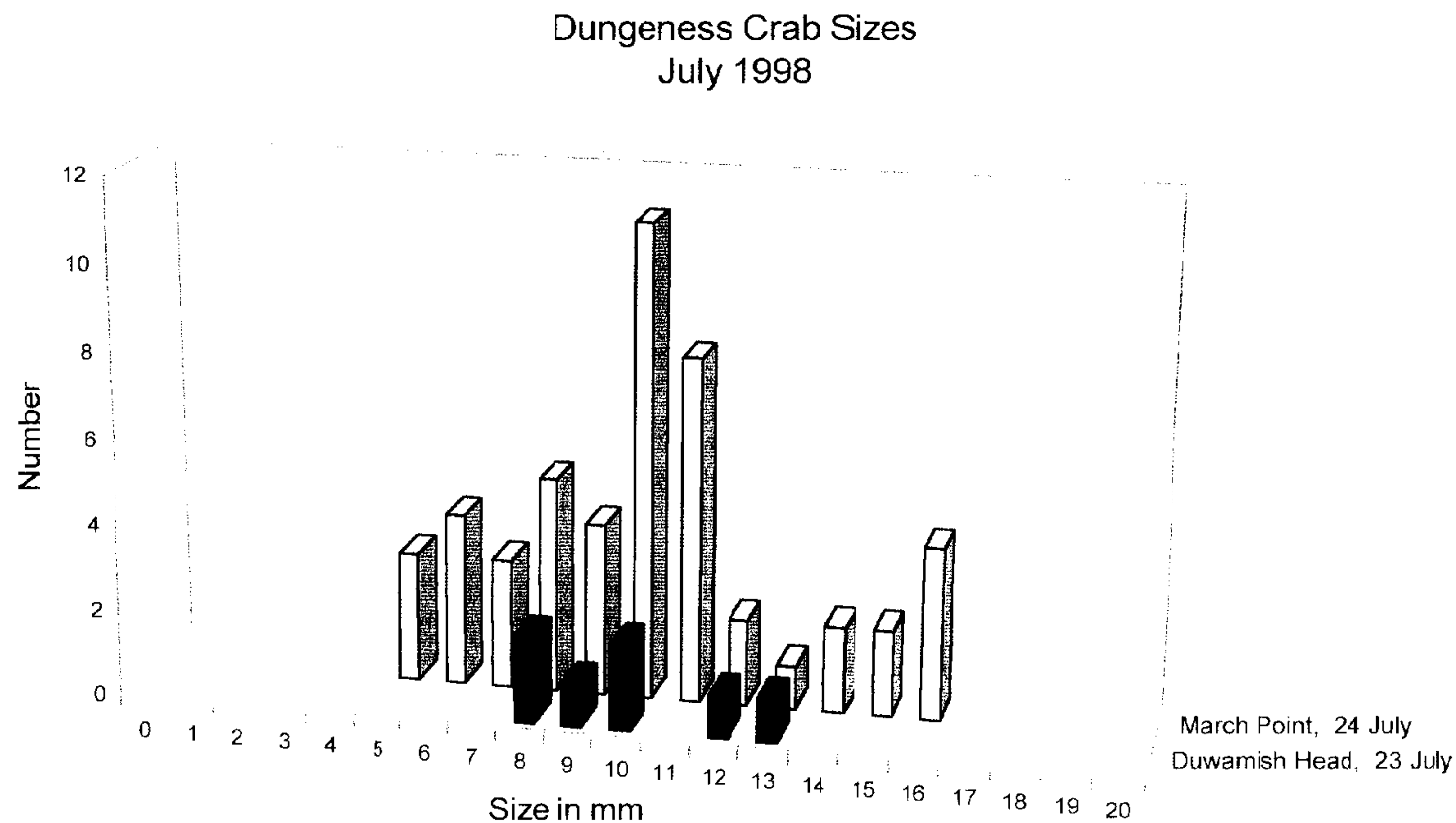

Figure 3. Size-frequencies of juvenile Dungeness crab sampled from Elliott Bay and March Point, north Puget Sound in July 1998.

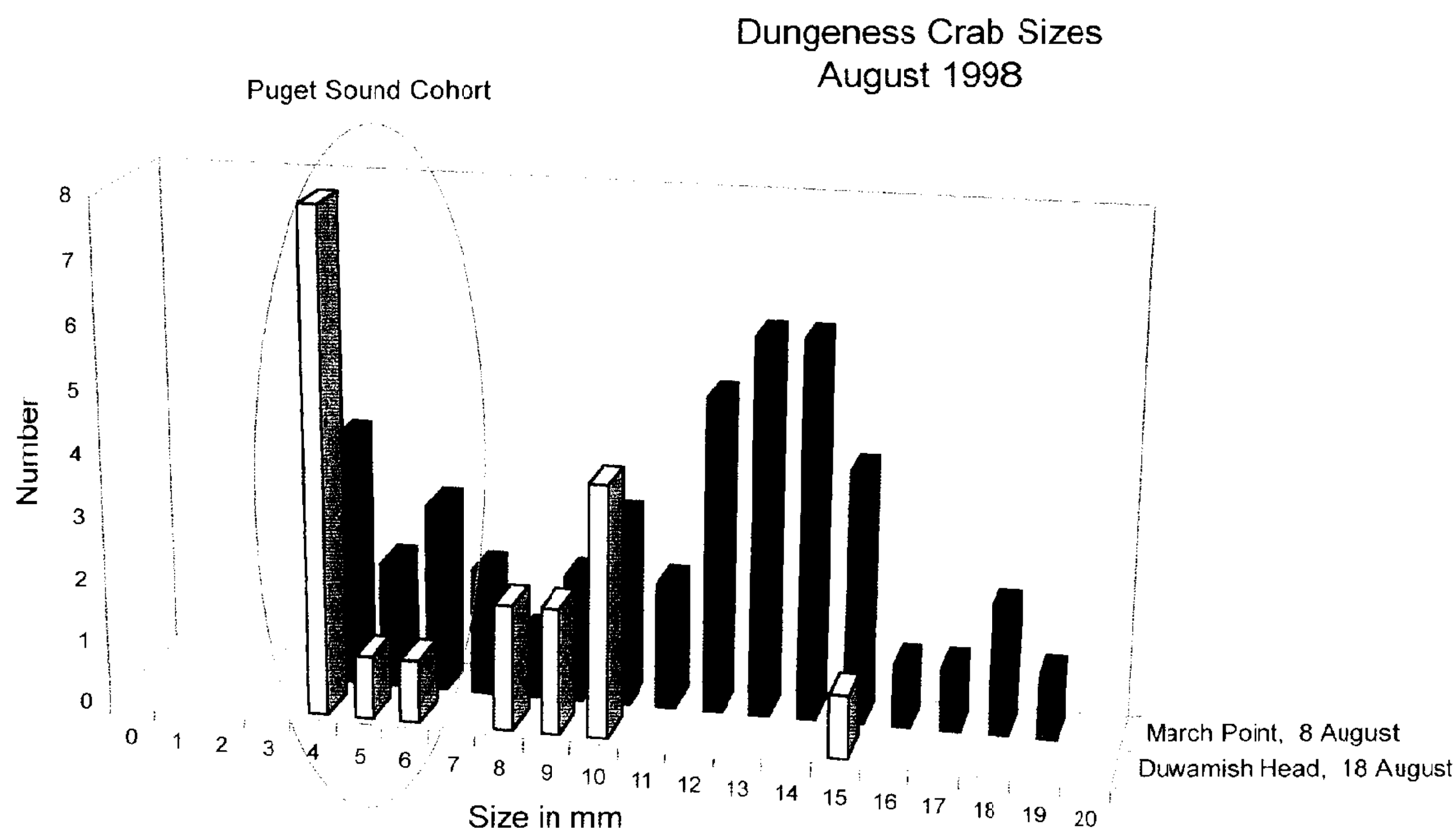

Figure 4. Size-frequencies of juvenile Dungeness crab sampled from Elliott Bay and March Point, north Puget Sound in August 1998. The oval highlights settlers from the later "Puget Sound cohort" in contrast to settlers from the early "Ocean cohort."